Head dynamics during emergency braking events

C. Di Loreto[a,c], J. Dutschke[b], M. Forrest[b], A. Van Den Berg[b], J. Chardonnet[c], F. Mérienne[c], J. Mackenzie[b] and B. Sandoz[a]

[a]Arts et Metiers, IBHGC, 151 Boulevard de l'Hopital 75013 Paris, France; [b]University of Adelaide, CASR, Gate 5 Frome Road SA 5005 Adelaide, Australia; [c]Arts et Metiers, LISPEN, II, 2 Rue Thomas Dumorey 71100 Chalon-Sur-Saône

Keywords*:* biomechanics; out-of-position; autonomous car; dynamics

1. Introduction

The on-going automation of our vehicles will take away the driver's attention from the road and the driving task. This results in the car occupants' paying less attention to the exterior environement of the vehicle and also to an increased prevalance of Out-Of-Position (OOP) seating arrangements. However, emergency braking events are still likely to happen and one can wonder about the effectiveness of restraint systems which are designed for in-position occupants, as reported by Subit *et al.* (Subit *et al.*, 2017).

This study aims to investigate the influence of several seating positions on the head kinematics of car occupants during various braking and speed conditions.

2. Methods

2.1 Subjects

Ten male subjects (35 ± 13 y/o) took part in the experiment. They were recruited through advertisement posters and an e-mail campaign within the University of Adelaide campus. Subjects were physically comparable (179 ± 4cm, 77 ± 3kg).

Subjects gave their consent to being involved in the experiment. The experiment was approved by the University of Adelaide's Office of Research Ethics, Compliance and Integrity (approval number H-2018-241).

2.2 Protocol

Subjects were equipped with three Xsens Inertial Measurement Units (IMU) located at the top of the head, along with the T1 and S1 vertebras. Another IMU was fixed on the car to record its dynamics during the experiment.

Subjects were seated in the front passenger seat of a car natively equipped with an automatic emergency braking (AEB) system. They were asked to arrange themselves in 3 specific positions: looking forward (forward), with their head turned to the side as if they were talking to the driver (talking) or tilting their head down as if they were texting (texting).

Two different braking conditions were applied: either through triggering the vehicle's AEB or via a pedal-robot robustly replicating a previously recorded human braking (Sandoz *et al.*, 2018). The AEB system was triggered using a standardised soft target, while a dedicated operator inside the car triggered the 'human' braking.

The experiment was conducted on an outside parking area that was sectioned-off from the public. The car travelled at constant speed controlled by the pedal-robot before the braking event (either 8 km/h or 15 km/h). Subjects were not aware of the trial conditions or when the braking was to occur.

Each of the 12 conditions was randomly tested 3 times, for a total of 36 trials per subject.

The acceleration levels of the car and the body segments have been studied, as well as the maximal Range Of Motion (ROM), defined as the difference between the maximum and the minimum relative angles between the head and the T1 vertebra during the head movement.

3. Results and discussion

3.1 Results

The maximum deceleration of the car during the braking event was different in the case of the human braking (0.53 ± 0.08 g) and the AEB braking (0.92 ± 0.14 g).

An ANOVA test on the head maximum acceleration revealed a significant difference among the 12 conditions ($p = 3.9\times10^{-10}$). A post-hoc Tukey HSD indicates that the differences are mostly found when the braking modality differs, and to a lesser extent, when the speed is different. Another ANOVA and Tukey HSD analysis done with the regrouping of the positions confirms this trend as only the grouping where the braking differs is significatively different. Thus, the braking modality appears to affect the level of head acceleration during the event: the AEB braking implies a higher head acceleration (1.49 ± 0.53g) than the human braking (1.14 ± 0.49 g).

Figure 1 shows a comparison in the evolution of head acceleration during a braking event for a human braking case and an AEB braking case, both at 8 km/h and with the same subject in the forward position.

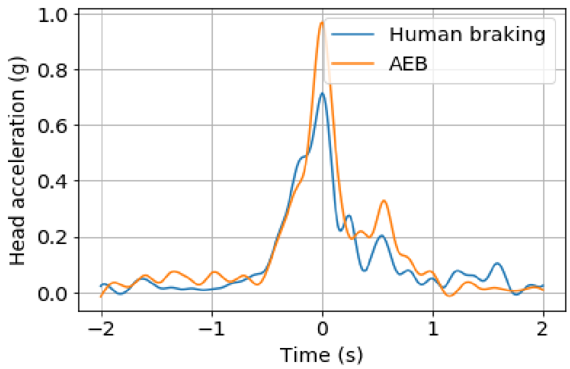

Figure 1: Head acceleration during AEB or human braking events, same subject in forward position at 8 km/h

An ANOVA test on the ROM revealed a significant difference among the 12 conditions ($p = 1.6 \times 10^{-4}$). A post-hoc Tukey HSD shows that significant differences in ROM are found when the positions differ. Another ANOVA and Tukey HSD analysis, done with the regrouping of the acceleration and speed for the same position, supports this observation. Thus, the position appears to affect the ROM observed during the event: the forward position corresponds to the lowest ROM (22.7 ± 11.4°), the talking position produces a ROM a bit higher (24.3 ± 10.2°) and the texting position results in an even higher ROM (30.3 ± 10.5°). Figure 2 shows boxplots of the ROM for the 12 conditions. For each given speed and braking modality, the same trend can be observed.

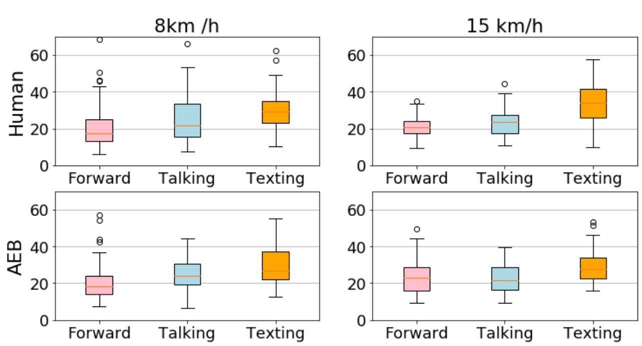

Figure 2: Mean maximum relative angle (°) between the head and the T1 vertebrae of the subjects

3.2 Discussion

Braking decelerations have been reproducible for each of the two speeds and braking methods.

Significatively higher levels of head acceleration have been observed for the AEB braking whereas no significant difference has been found in terms of ROM. This is likely to be explained by the audible alarm system which is automatically triggered one second before the AEB activation. This may have allowed the subjects to prepare themselves, resulting in a comparable ROM despite the acceleration being higher.

While no significant difference was found in terms of head acceleration between the three different positions, there was a significant difference in the observed ROM. A hypothesis could be that the ROM is affected by the subject's view of the road in their peripherical vision. Without a view of the road, the subjects must rely on their inner ear alone to register the acceleration. This may induce a higher latency, and thus, the subjects might not be able to anticipate braking as well as they would when they are looking the road. This may also change their head stabilization strategy.

It would have been interesting to have selected the subjects according to the classification proposed by (Vibert *et al.*, 2006): floppy and stiff subjects. The ROM observed should have been higher for floppy subjects, so may have been the differences observed.

4. Conclusions

In this paper, we presented a pilot study aimed at understanding head stabilization strategies during braking events at low speed for OOP seating arrangements. The results presented here show that the seating position of a vehicle occupant and the modality of braking may change their kinematic response. We suggest that this should be considered in future research.

Acknowledgements

Cédric Di Loreto was awarded a PHC FASIC PhD travel grant. Baptiste Sandoz and Cédric Di Loreto also benefited from funding provided by the government of South Australia. Cédric Di Loreto, PhD, is founded by the Fondation Arts et Métiers through the Réseau Santé.

References

Sandoz B., Bucsuház K., Van Den Berg A., Dutschke J. & Mackenzie J. (2018). Acceleration of a car passenger during automatic emergency braking. *World congress of Biomechanics*.

Subit D., Vezin P., Laporte S., & Sandoz B. (2017). Will automated driving technologies make today's effective restraint systems obsolete? *American Journal of Public Health*, *107*(10), 1590–1592.

Vibert N., Hoang T., Gilchrist D.P.D., MacDougall H.G., Burgess A.M., Roberts R.D., Vidal P.P. & Curthoys I.S. (2006). Psychophysiological correlates of the inter-individual variability of head movement control in seated humans. *Gait and posture*, 23, 355-363.

***Corresponding author. Email: cedric.di-loreto@ensam.eu**